SNS Ring
Transverse and Longitudinal Halo Measurements

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Outline

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    - Halo Scraper
    - Detectors
    - Data Acquisition
    - Measurement
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    - Resonant kicker – Gap Cleaner
    - Detector
    - Data Acquisition
    - Measurement
    - Calibration
- Summary

Introduction

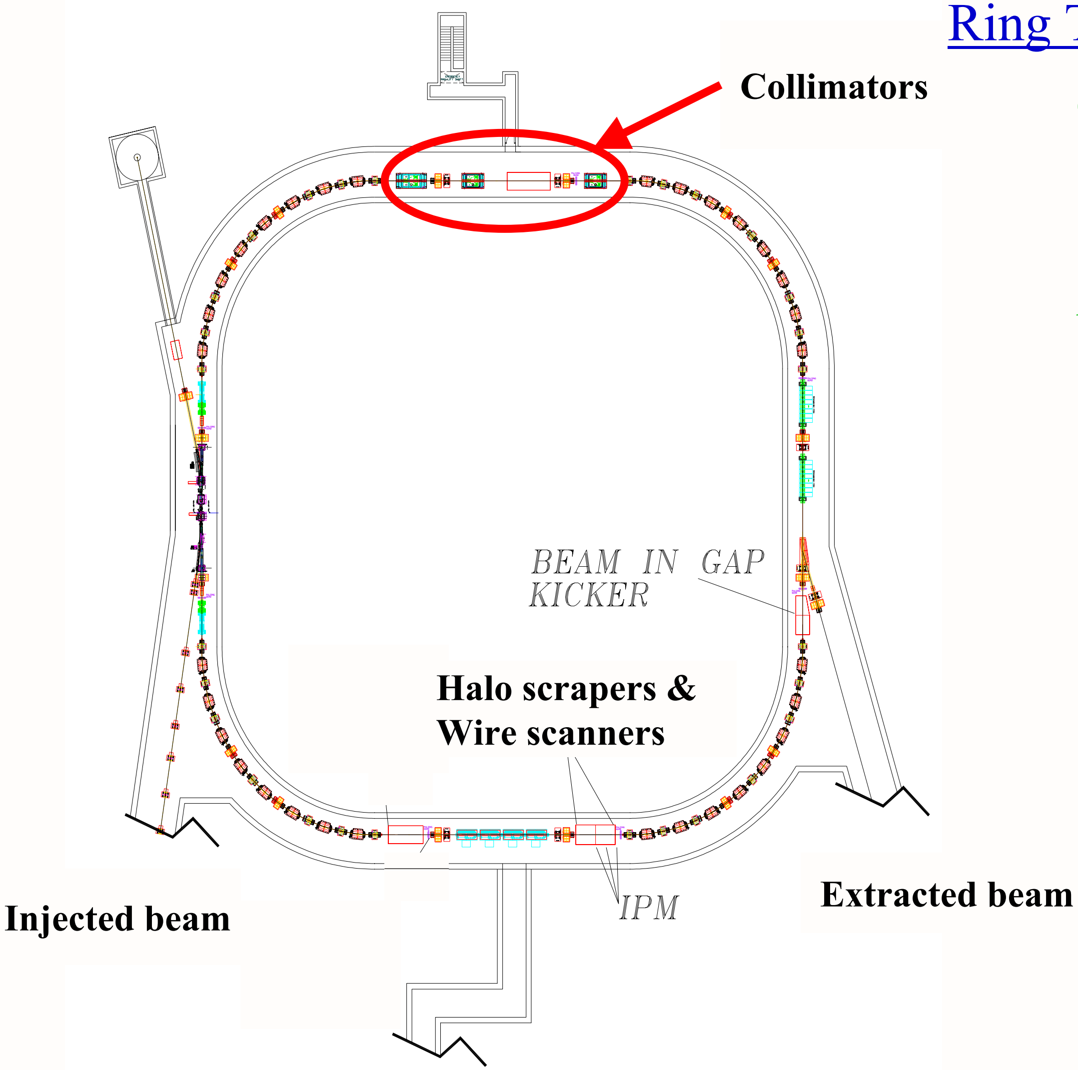
Halo measurements: essential for understanding beam loss & minimize activation; requires profile measurements of beam tails 4 orders of magnitude below the peak beam intensity. Range of 1 turn to 1000 turns.

Wire scanners and IPM will likely not have good resolution in the tails.

Transverse and Longitudinal halo measurements handled separately.

This talk a discussion of possible measurement solutions.

SNS Ring layout



Ring Transverse Halo Diagnostics

Covering Ring:
- 70 BLM
- 12 FBLM

At Halo Scraper:
- FBLM
- Secondary Emission

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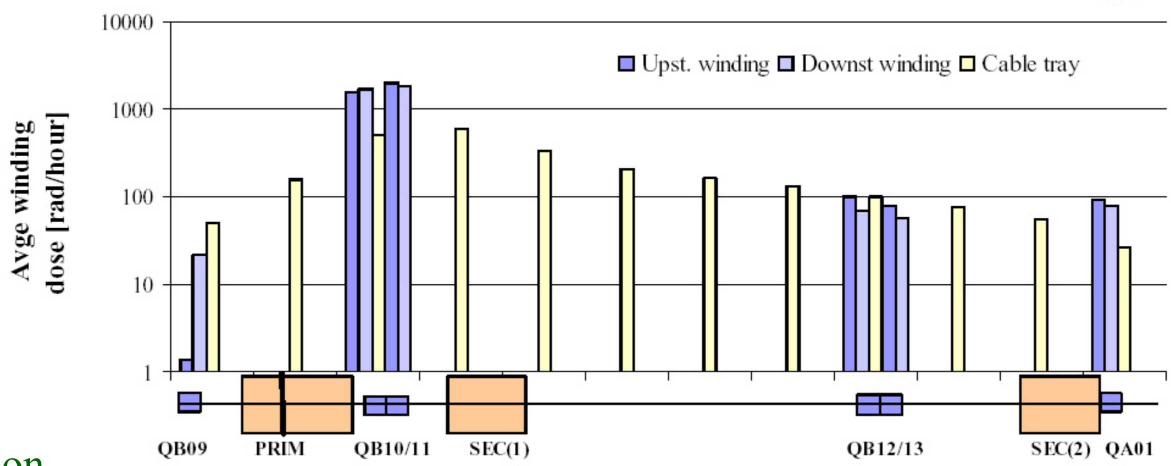
Why we need a Halo Scraper

Estimate of Controlled Losses at the Collimator

Source	Fraction
Beam In gap	1.0×10^{-4}
Excited H^0 at foil	1.3×10^{-5}
Space Charge Halo	1.9×10^{-3}
Energy Straggling at foil	3.0×10^{-6}

Loss Distribution Near Collimator



N. Catalan-Lasheras

Extend WS profile data into halo.
Better measurement at cooler location.
High losses near collimator
High background, resolution limitations.

BLM System resolution:

1 W/m is about equal to 100 mR/hr activation. To get beam on dose rate multiply by 1000 so it is 100 R/hr. But, this is average and with a 6% duty factor we must multiply by 16 to get peak, or 1.6kR/hr. BLM generates 20 pA/R/hr so we get 32 nA signal.

So if we can resolve 1% of this we can see 1% of 1600 R/hr or 16 R/hr peak during the pulse. Levels near the primary collimator 50R/hr average x 16 = about 800R/hr peak.

Halo Scraper

Halo Scraper installed at wire scanner locations, near IPM.

- Not designed yet.
- Must be much larger than 32μ wire used in wire scanner
  - need more losses yielding larger signal from beam halo.
  - Possibly 1mm thick, 1cm deep, Tungsten?
  - Limited motion control, heating issues
    - Not scanned across beam core.

Simulations Needed:

- Dimensions and material?
- Best place to locate detectors based on particle tracking?
  - Collimator region has high levels due to controlled losses

Detectors & DAQ

- **Detectors**
  - Photomultipliers (FBLM’s)
    - Electron Tubes Inc. 9813KB
  - Ion Chamber BLMS
    - New SNS design produced by LND, Inc.
    - Argon filled, 70nC/Rad, 20pA/Rad/hr
  - Halo scraper SEM.
  - Telescope does not appear attractive, pile-up problems.

- **Processing Electronics**
  - Photomultipliers (FBLM’s)
    - Wideband buffer/amplifier, fast digitizer
  - Ion Chamber BLM’s
    - Use global BLM’s system AFE & digitizers.
  - Secondary Emission electronics provided by LANL, also used at wire scanners.

Scanner/Scraper Beam Box Assembly

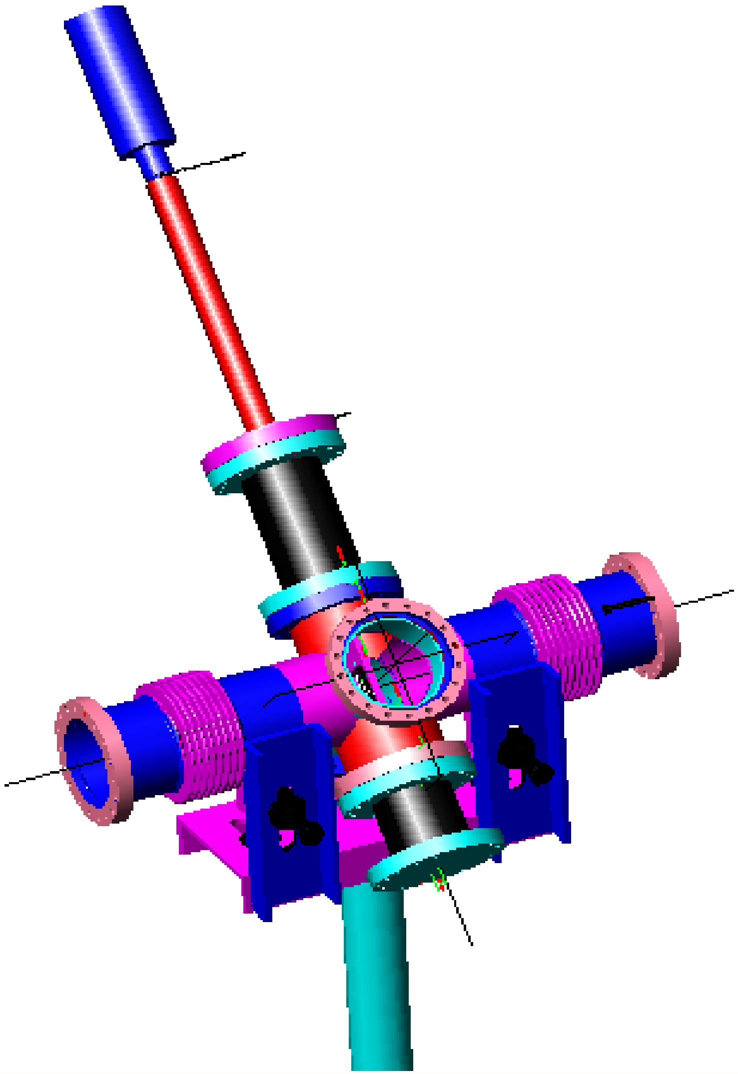
Profile measurements

LANL: Preliminary Design of Wire Scanner/Scraper and Beam Box Interface in the HEBT, the Ring and the RTBT Areas.

Scraper (To be designed)

- **32µ Carbon Wire**
  - **positioning accuracy of 0.3 mm**
- **Flange/tubing Size:**

10”/8”OD (Ring, RTBT)



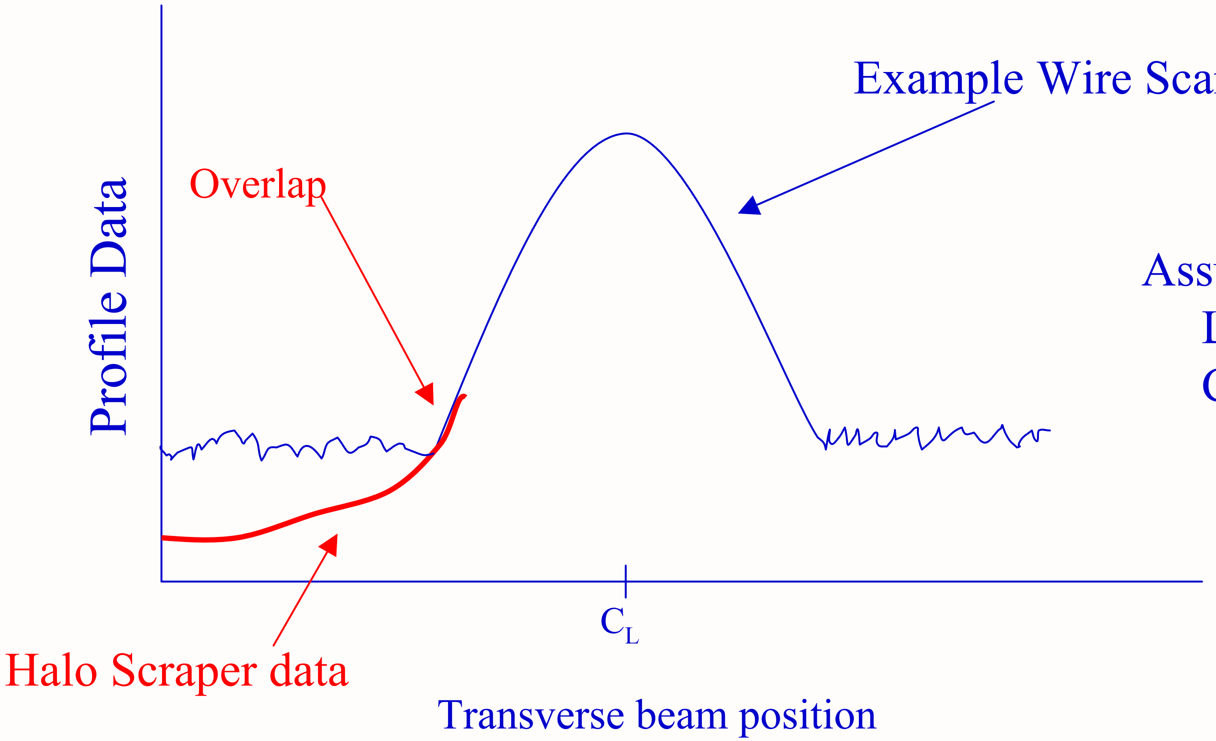
Transverse Halo Measurement

Wire Scanner profiles:

S/N expected about 8:1 for wire at center of beam, M. Plum estimate, July 2002.
Need signal averaging to get a reasonable profile.

Halo Scraper:

Scan halo scraper far enough in to overlap good wire scanner profile data.



Assume:

Losses linear with intensity
Consistent loss distribution

Longitudinal Halo – Beam In Gap

Accelerator Physics BIG requirements 0 – 100mA, 20% relative accuracy.

BCM's (0.5% resolution) & wall current monitor not able to resolve beam in gap.

Use resonant kicker to clean gap.

Measure beam in gap losses during the gap time.

Longitudinal Halo – Beam In Gap

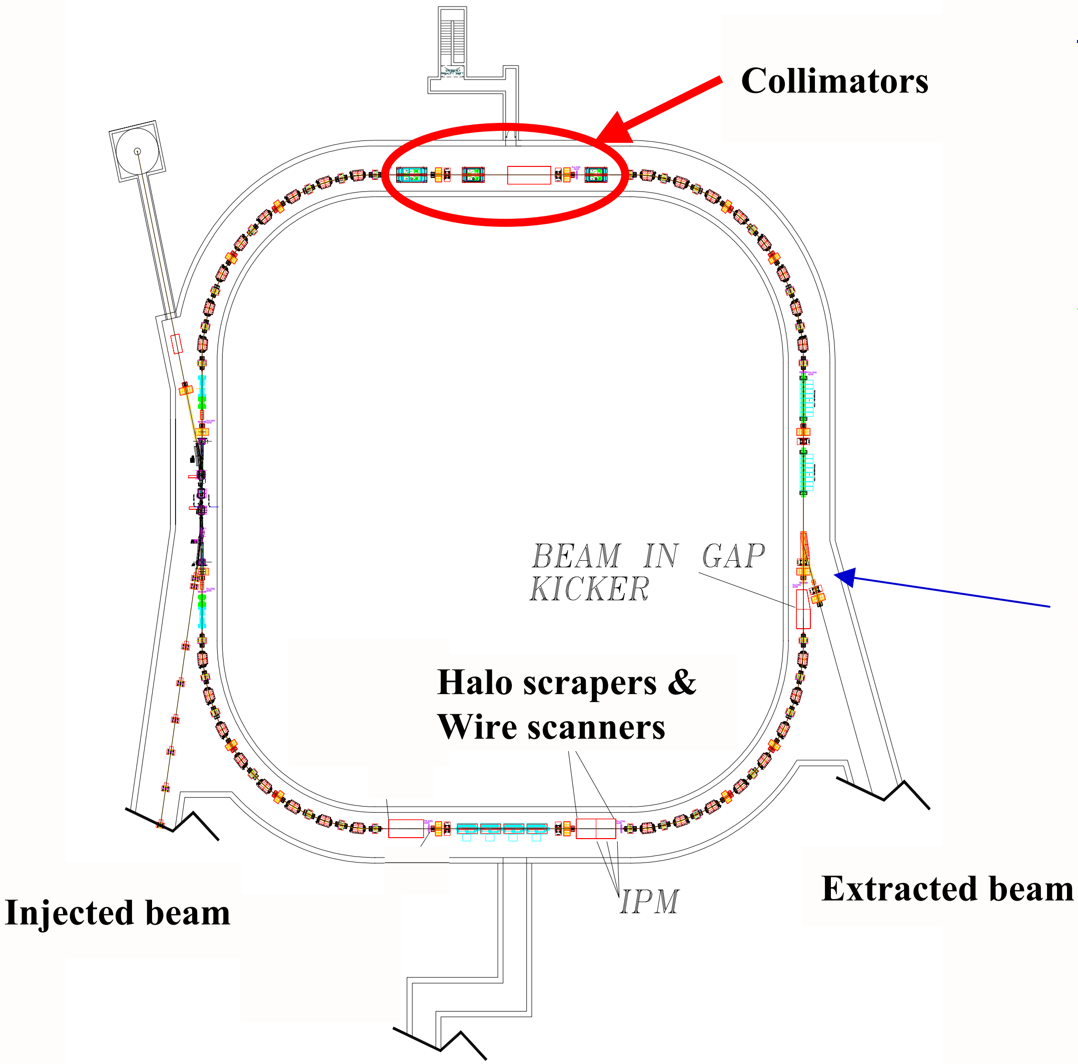
- **Linac: Should be no beam in the gap**
  - Chopper should be 100% efficient
  - Linac team claims nothing can make it from one end of the Linac to the other, and at the same time find its way from the mini-bunch to the gap.
- **Ring: during accumulation expect 10^{-4} controlled losses due to**
  - **nuclear scattering, foil losses**
  - **RF noise, collimation inefficiency, and more**

• These effects, result in >100W deposited in the extraction region. Much greater than the 1W/m safety level.

• Experience has taught us that in existing machines there is beam in the gap, claimed to sometimes be at the percent level

• Uncontrolled Loss budget is 10^{-4}.

SNS Ring layout



Ring BIG Diagnostics

Covering Ring:
- 70 BLM
- 12 FBLM

At Halo Scraper:
- FBLM
- Gated MCP/PMT

Collimator:
- Gated MCP/PMT

Extraction region:
- Gated MCP/PMT

BIG Cleaner & Monitor

BIG Kicker

Gap beam will be vertically kicked onto the collimators/scraper for the last 60 to 100 turns of the accumulation cycle by three 1.5m long 50 Ohm stripline kickers during normal operations. This process can be done anytime in the cycle to study the development of the beam in gap.

Bunch length 675 ns

Gap length 275 ns

Rise time 10-20ns for 10-90%

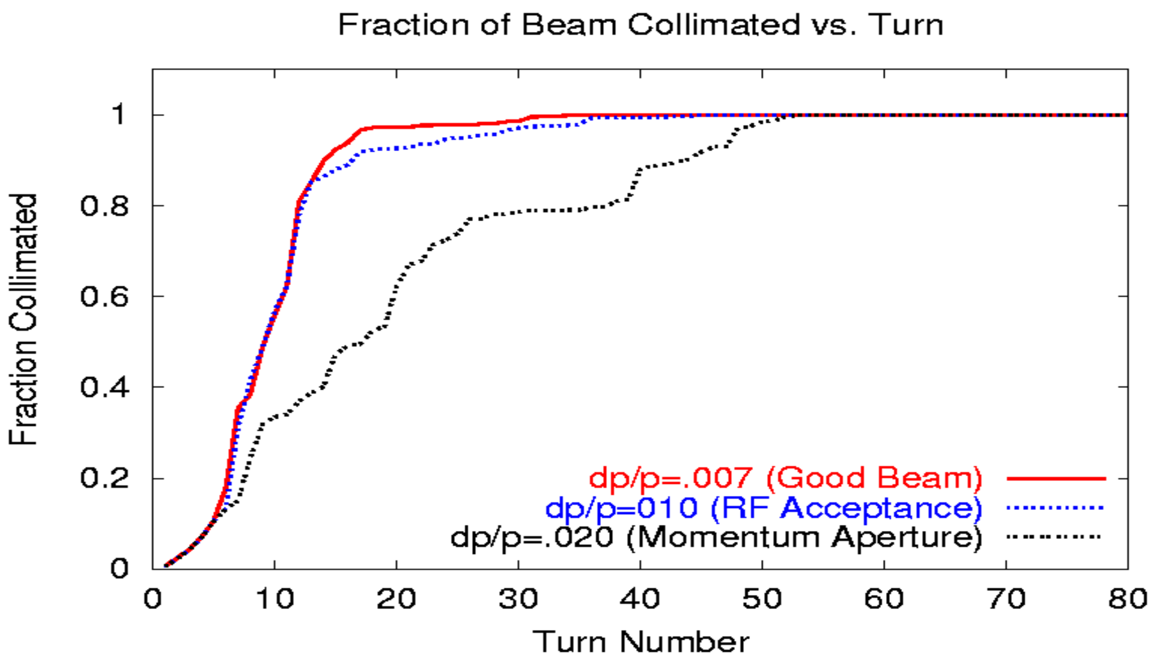
Kickers powered by 7KV pulsers driving opposing striplines with opposite polarity. Kick strength and number was determined utilizing particle-in-cell tracking code.

BIG Monitor: Need gating to avoid saturation from controlled losses while bunch passes by.

Loss pattern observed with a gated PMT/MCP at:

Collimator	kicked gap beam destination
Halo scraper	temporary limiting aperture, studies
Extraction Region	uncleaned gap beam destination

BIG Cleaning Simulation



1mrad vertical kick

S. Cousineau et al EPAC 2002

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Detector for BIG

Gated high gain, high speed detectors

–Hamamatsu R5916U-50

- Gateable Micro-channel plate (5–10,000ns gate width)
- 10^8 switching ratio
- 10^5 gain
- 0.18 ns rise time
- Need Scintillator?
- Support electronics needed, bias, trigger . ..

Gate detector off during bunch passing to keep from saturating.

Gated MCP/Photo-multiplier Tubes

HAMAMATSU

GATEABLE MICROCHANNEL PLATE PHOTOMULTIPLIER TUBE (MCP-PMTs)

R5916U-50 SERIES

Featuring Fast Gating Function with Improved Time Response and Switching Ratio

FEATURES

- High Speed Gating by Low Supply Voltage (+10V)
  - Gate Rise Time : 1 ns [1]
  - Gate Width : 5 ns
- Fast Rise Time : 180 ps
  - Narrow TTS [2] : 90 ps
- High Switching Ratio : 10^8 at 500 nm
- Low Switching Noise
- Low Dark Noise
- Variety of Photocathode Available

APPLICATIONS

- Environmental monitoring
- Satellite laser ranging
- Fluorescence decay analysis

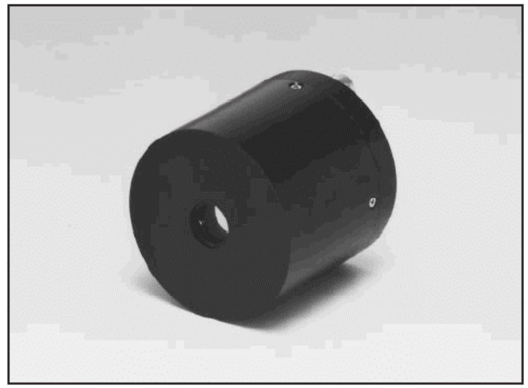
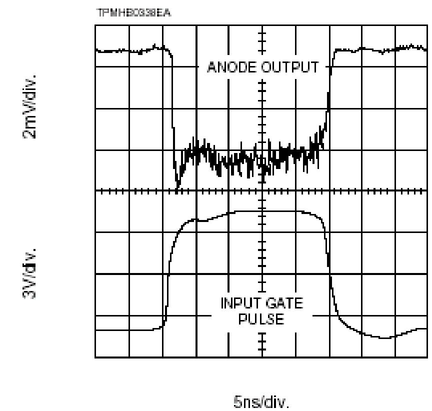


Figure 10: Gate Pulse Response



Supply Voltage : -3000V
Wavelength : 410nm
Ambient Temperature: 25°C
Gate Pulse Height : 10V
Gate Pulse Width : 25ns

Manufacturer recommends 1% duty cycle.
We need 25% for short periods of time, 60μs.
Have to be careful we stay within power specifications.

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Wideband Amplifier for FBLM

CAEN *Tools for discovery*

Nuclear Physics

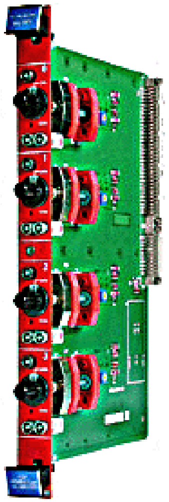
V974

4 Channel Variable Gain Fast Amplifier

new

Family: VME

- x10 Adjustable Gain (x1 Steps)
- 0÷150 MHz Input Bandwidth
- 50 Ohm Input Impedance
- ±2 V Output Dynamics
- Drives 50 Ohm Loads
- Cascadeable Channels
- <3 ns Rise Time
- <3 ns I/O Delay



Overview

The Model V974 is a 4 channel fast rise time amplifier housed in a 1-unit VME module; each channel features a voltage gain variable in the range 0 ÷ 10.

Channels are non-inverting and bipolar: they amplify both positive and negative signals.

Gain setting can be performed independently for each channel via four 11-position rotary handles.

Channels can be cascaded in order to obtain larger gain values. Each channel is provided with three LEMO 00 connectors, one for the input and two (bridged) for the output.

The board features a ±2 V output dynamics. 4 screw-trimmers (one per channel) allow the offset calibration which operates over a ±25 mV range.

The features include an input over voltage protection.

Data Acquisition

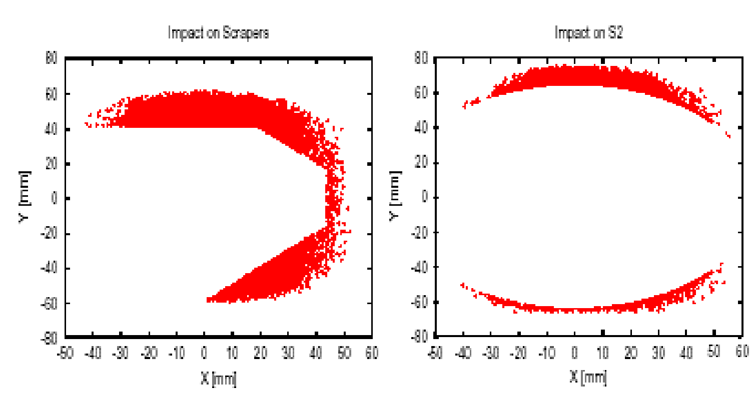
- With < 300 nsec gap, need high sample rate ADC to acquire signal, such as:
  - Dedicated 1 GSa/s scope under Labview control …….Very expensive
  - Commercial PCI Fast ADC module
    - Acquiris (Module under test at ORNL)

–DP-105	0.5 GSa/s,	8-bit	1 Mb	= 150 samples
–DP-110	1.0 GSa/s,	8-bit	2 Mb	= 300 samples
–DP-210	2.0 GSa/s,	8-bit	4 Mb	= 600 samples

- CompuScope 82G (Gage-Applied) – 2GSa/s, 8-bit = 600 samples

Ring BIG Measurement Approach

- Limiting apertures are the collimators
  - –Locate detector near collimators (further study needed)
  - –Collimators designed to intercept controlled losses
  - –Beam cleaned from gap will be lost in collimators, 75% Primary, 25% Secondary
  - –In place all the time – allows measurement during normal operation
  - –Will be "warm" area – possible high background which may make fine measurement difficult
- Beam Halo measurement scraper can be used for higher resolution BIG measurement
  - –Becomes temporary limiting aperture
  - –Lower background region
  - –Cannot be used continually – losses too high
- Use both approaches



S. Cousineau et al EPAC 2002

Extraction BIG Measurement

1. Extract beam normally to target at various times in the cycle.

   Observe losses with gated detector.

   - Factor of 15-30 improvement in instantaneous loss over BIG kicker resonant extraction.
   - Losses are in the open at extraction region, rather than buried in the collimator, where they are difficult to see by design

- Estimate of cleaning efficiency.
  - Measure loss at extraction septum during gap with BIG cleaner Off and On.

Calibration Techniques

Technique 1. BIG kicker

- Inject 1 turn (0.1% of full beam, 15mA)
- Execute resonant gap cleaning during the beam pulse
- Measure turn-by-turn change in total charge with BCM
- Measure losses at the collimator (or Halo Scraper), turn-by-turn, over kick duration using gated MCP/PMT.
- Also measure losses with FBLM's & BLM's.

Technique 2. Extraction kicker

- injecting 1 turn by and
- extract on the bunch.
- Calibrate losses at extraction region

- Need Accelerator Physics studies to estimate accuracy of the measurement
  - Can 20% be achieved?
  - Relative measurement still important

Summary

- Halo measurement techniques
  - Transverse, enhanced wire scanner profile measurement
    - Interacts with Halo Scraper, Collimator, Wire
    - Detectors
      - FBLM, BLM, SEM
  - Longitudinal - Beam in Gap
    - Clean Gap with resonant kicker
    - Detect loss with Gated MCP/PMT
- Calibration
  - Kick (small) measurable amounts of beam.
  - Measure losses.
- **Plans:**
  - Simulation and analysis needed for Halo scraper:
      - Transverse halo, & BIG cleaning.
  - Design Halo Scraper
  - Purchase and test Gated MCP/PMT
  - Additional simulations:
    - Loss pattern at extraction region due to BIG.
    - Loss pattern while extracting on 1 turn, for calibration.